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EFFECTS OF ELEVON DEFLECTION ON THE AERODYNAMIC CHARACTERISTICS OF A HYPERSONIC GLIDER MODEL AT MACH NUMBERS OF ABOUT 0.62 AND 0.96

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EFFECTS OF ELEVON DEFLECTION ON THE AERODYNAMIC CHARACTERISTICS OF A HYPERSONIC GLIDER MODEL AT MACH NUMBERS OF ABOUT 0.62 AND 0.96*

Charles D. Trescot, Jr., F. E. West, Jr., and
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SUMMARY

A wind-tunnel investigation has been made to determine the effects of symmetrical and unsymmetrical elevon deflection on the static aerodynamic characteristics of a hypersonic glider model. The model had a highly swept clipped-tip low triangular wing with a cranked leading edge and upper-surface tip-mounted vertical tails with 0.1° toe-out. Tests were made at angles of sideslip of 0° and about 5° at Mach numbers of about 0.62 and 0.96 through an angle-of-attack range from about -1° to 19°. Average Reynolds numbers, based on the wing mean aerodynamic chord, were 2.64×10^{6} and 2.75×10^{6} at Mach numbers of 0.62 and 0.96, respectively. Transition strips were applied near the leading edge of all model configurations.

The results indicate that, at both test Mach numbers, the slopes of the normal-force curves were linear at low angles of attack but increased at moderate angles of attack. Adequate elevon control was available for longitudinal trim at both test Mach numbers. At all symmetrical elevon deflections investigated, the configuration had a tendency to become unstable at moderate angles of attack for a Mach number of about 0.62 and had a tendency toward decreased stability at moderate angles of attack for a Mach number of about 0.96. At both test Mach numbers, elevon rolling-moment effectiveness generally decreased with increases in angle of attack. The model had positive effective dihedral over most of the angle-of-attack range at both Mach numbers and had almost neutral directional stability at a Mach number of about 0.62 and positive directional stability at a Mach number of 0.95.

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INTRODUCTION

A series of investigations have been undertaken at various Langley wind-tunnel facilities to provide information on the aerodynamic characteristics of several hypersonic glider models from landing to hypersonic speeds. The purpose of the present investigation was to provide high subsonic information on the effect of elevon deflection on the static aerodynamic characteristics of one of these hypersonic glider models.

The results show the effect of symmetrical and unsymmetrical elevon L
deflection on the static longitudinal and lateral stability characteris- 7
tics of the model. The tests were conducted in the Langley transonic 6
blowdown tunnel at Mach numbers of about 0.62 and 0.96, at angles of 0
attack from about -1° to 19°, and at angles of sideslip of 0° and about 5°. High subsonic results for some of the other configurations investigated in the program are presented in references 1 and 2.

SYMBOLS

The forces and moments are referenced to the body axes which have their origin on the body center line at 64 percent of the body length.

A	aspect ratio
b	wing span
C_N	normal-force coefficient, $\frac{\text{Normal force}}{q_\infty S}$
ΔC_N	incremental normal-force coefficient due to control deflection
C_Y	side-force coefficient, $\frac{\text{Side force}}{q_\infty S}$

$C_{Y_\beta} = \frac{\partial C_Y}{\partial \beta}$ per degree

C_l	rolling-moment coefficient, $\frac{\text{Rolling moment}}{q_\infty Sb}$

$C_{l_\beta} = \frac{\partial C_l}{\partial \beta}$ per degree

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C_m pitching-moment coefficient, $\frac{\text{Pitching moment}}{q_\infty S\bar{c}}$

ΔC_m incremental pitching-moment coefficient due to control deflection

C_n yawing-moment coefficient, $\frac{\text{Yawing moment}}{q_\infty Sb}$

$C_{n_\beta} = \frac{\partial C_n}{\partial \beta}$ per degree

$\bar{c}$ wing mean aerodynamic chord

M_∞ free-stream Mach number

q_∞ free-stream dynamic pressure

r radius

S wing total area

α angle of attack

β angle of sideslip

δ elevon deflection, positive value indicates downward deflection

Subscripts:

L left

R right

av average deflection of symmetrically deflected elevons

Model designations:

B_3 fuselage

V_5 vertical tail

W_5 wing

MODELS AND APPARATUS

The model had a highly swept clipped-tip low triangular wing with a cranked leading edge and upper-surface tip-mounted vertical tails with 0.1° toe-out. A drawing of the model (designated $B_3W_5V_5$) is presented in figure 1 and a photograph of the model is shown in figure 2. The plain flap-type elevons were hinged about the line shown in figure 1. All parts of the model were constructed of steel.

The model was mounted on a five-component electrical strain-gage balance that was attached to the sting support system of the Langley transonic blowdown tunnel which has an octagonal slotted throat section measuring 26 inches between flats. The moment center of the model was located at 45.5 percent of the wing mean aerodynamic chord, which corresponds to 64 percent of the body length.

L
7
6
0

TESTS

Normal-force, pitching-moment, rolling-moment, yawing-moment, and side-force balance data were obtained for all configurations. The tests were made at tunnel stagnation pressures of 31 and 25 pounds per square inch absolute for Mach numbers of about 0.62 and 0.96, respectively, and through an angle-of-attack range at sideslip angles of 0° and about 5°. The angle of attack was varied from about -1° to a maximum of about 19°. Average Reynolds numbers, based on the wing mean aerodynamic chord, were 2.64×10^6 and 2.75×10^6 for Mach numbers of 0.62 and 0.96, respectively.

The various elevon deflections investigated at an angle of sideslip of 0°, which are listed as δ_L and δ_R, respectively, were 0° and 0°, 0° and -10.2°, -9.9° and -10.2°, 10.5° and -10.2°, 10.5° and 10.5°, 0° and -19.8°, and -19.9° and -19.8°. Elevon deflections tested at an angle of sideslip of about 5° were 0° and 0°, and -19.9° and -19.8°.

For all tests transition strips, consisting of 0.001- to 0.002-inch carborundum grains blown on a thin coating of wet shellac, were applied to the model configurations. (See ref. 3.) The strips were about 1/16 of an inch wide and the grains covered 5 to 10 percent of the strip area. The leading edges of the transition strips were located on the upper and lower surfaces of the wing at 5 percent of the local chord, on both sides of the vertical tails at 7.5 percent of the local chord, and on the body at the line of tangency between the spherical nose and the forebody cone.

PRECISION

Estimated accuracy of coefficients (based on balance accuracy) and other pertinent parameters are as follows:

C_N	± 0.01
C_m	± 0.002
C_l	± 0.001
C_n	± 0.003
C_Y	± 0.007
α, deg	± 0.1
β, deg	± 0.1
M_∞	± 0.02

No corrections due to tunnel-wall effects or sting interference have been applied to the data. It is believed, however, that these corrections would be small. (See refs. 4 and 5.)

RESULTS AND DISCUSSION

The effects of symmetrical elevon deflection on the longitudinal aerodynamic characteristics are shown in figures 3 and 4 for Mach numbers of about 0.62 and 0.96, respectively. Summary curves showing the effect of Mach number on the variation of the longitudinal stability parameter and the center-of-pressure location with normal-force coefficient are shown in figure 5 for an elevon deflection of 0°. The effects of unsymmetrical elevon deflections on the lateral and incremental longitudinal aerodynamic characteristics at Mach numbers of about 0.62 and 0.96 are shown in figures 6 and 7, respectively. Figure 8, based on tests at angles of sideslip of 0° and about 5°, shows the effect of angle of attack at both Mach numbers on the lateral stability derivatives for the model with and without the elevons deflected.

Longitudinal Aerodynamic Characteristics

Normal-force characteristics.- The normal-force curves of figures 3(a) and 4(a) show that the variation of normal-force coefficient with angle of attack was nonlinear. In the low angle-of-attack range, the curves were generally linear but at moderate angles of attack, the slopes increased. These increases in slope are typical of low-aspect-ratio wings at both subsonic and transonic speeds (ref. 6) and are associated with viscous effects on the upper wing surface. At both test

Mach numbers the slopes of the normal-force curves at $C_N = 0$ were greater than that predicted by linear theory for a plain wing. These greater slopes are associated with the end-plate effect of the vertical tails; that is, the tails increased the model effective aspect ratio. Increasing the Mach number from about 0.62 to about 0.96 resulted in increases in the slope of the normal-force curves, as would be expected.

Pitching-moment characteristics.- The effect of symmetrical elevon deflection on the pitching-moment coefficients at Mach numbers of about 0.62 and 0.96 indicate that adequate elevon control was available for longitudinal trim throughout the angle-of-attack range investigated in L
the present tests. (See figs. 3(b) and 4(b).) Generally, the control 7
effectiveness was essentially constant through the angle-of-attack 6
range for both test Mach numbers. There was, however, a small decrease 0
in control effectiveness at the higher angles of attack investigated at a Mach number of about 0.96 for a symmetrical elevon deflection of 10.5°. (See figs. 4(b) and 4(c).)

At a Mach number of about 0.62, figure 3 shows that the configuration had a tendency to become unstable at moderate angles of attack for all symmetrical control deflections investigated. Figure 5(a) shows that, at a Mach number of 0.62, the configuration without elevons deflected was slightly unstable for values of normal-force coefficients above 0.25. Generally, the model was stable at a Mach number of about 0.96, although there was a tendency toward decreased stability in the moderate angle-of-attack range.

Figure 5(b) shows that increasing the Mach number from about 0.62 to 0.96 for a control deflection of 0° resulted in a forward shift of center of pressure at low values of normal-force coefficients. Above normal-force coefficients of about 0.25, there was a rearward shift of the center of pressure as the Mach number was increased from 0.62 to 0.96.

Lateral Aerodynamic Characteristics

Lateral control effectiveness.- The elevon rolling-moment effectiveness generally decreased with increases in angle of attack as shown in figures 6 and 7 for Mach numbers of about 0.62 and 0.96, respectively.

A larger decrease in elevon rolling-moment effectiveness occurred for the oppositely deflected elevons $\left(\delta_L = 10.5^\circ,\ \delta_R = -10.2^\circ\right)$ at both Mach numbers than that obtained for the unsymmetrical elevon deflection $\left(\delta_L = 0^\circ,\ \delta_R = -19.8^\circ\right)$, particularly at angles of attack above 8°. The effect on rolling-moment coefficient of increasing the Mach number from about 0.60 to 0.94 was small.

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The yawing-moment coefficients due to elevon deflection were generally small. The configuration with $\delta_L = 10.5^\circ$ and $\delta_R = -10.2^\circ$ had adverse yawing moments.

Stability derivatives.- Figure 8 (determined from data at angles of sideslip of 0° and 5°) shows that for an elevon deflection of 0° the model had positive effective dihedral over most of the angle-of-attack range at both Mach numbers. This configuration also had almost neutral directional stability at a Mach number of 0.62 and positive directional stability at a Mach number of 0.95.

Deflecting the elevons about -20° $\left(\delta_L = -19.9^\circ,\ \delta_R = -19.8^\circ\right)$ generally decreased the effective dihedral at both Mach numbers and also decreased directional stability above an angle of attack of 5° for a Mach number of 0.95.

CONCLUSIONS

A wind-tunnel investigation has been made to determine the effect of elevon deflection on the aerodynamic characteristics of a hypersonic glider model. The model had a highly swept clipped-tip low triangular wing with a cranked leading edge and upper-surface tip-mounted vertical tails with 0.1° toe-out. Tests were made at angles of sideslip of 0° and about 5° at Mach numbers of about 0.62 and 0.96. Results of the investigation, which was conducted through an angle-of-attack range from about -1° to 19°, indicate the following:

1. At both test Mach numbers the slopes of the normal-force curves were linear at low angles of attack but increased at moderate angles of attack.

2. Adequate elevon control was available for longitudinal trim at both test Mach numbers.

3. At all symmetrical elevon deflections investigated, the configuration had a tendency to become unstable at moderate angles of attack for a Mach number of 0.62 and had a tendency toward decreased stability at moderate angles of attack for a Mach number of about 0.96.

4. At both test Mach numbers, elevon rolling-moment effectiveness generally decreased with increases in angle of attack.

5. The model had positive effective dihedral over most of the angle-of-attack range at both Mach numbers and had almost neutral

directional stability at a Mach number of about 0.62 and positive directional stability at a Mach number of 0.95.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., September 3, 1959.

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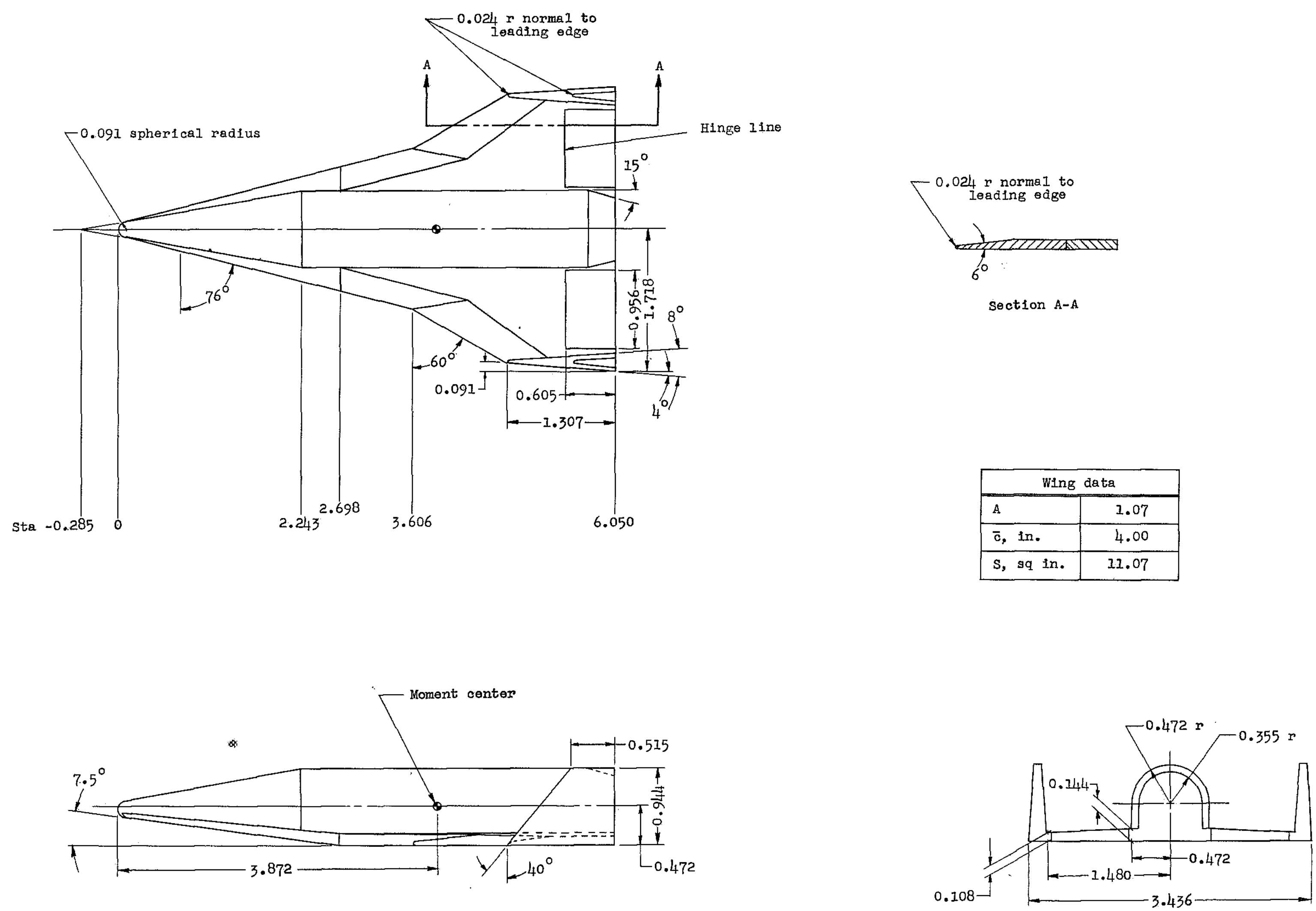

Wing data	
A	1.07
$\bar{c}$, in.	4.00
S, sq in.	11.07

Figure 1.- Sketch showing design dimensions of model $B_3W_5V_5$. All dimensions are in inches unless otherwise noted.

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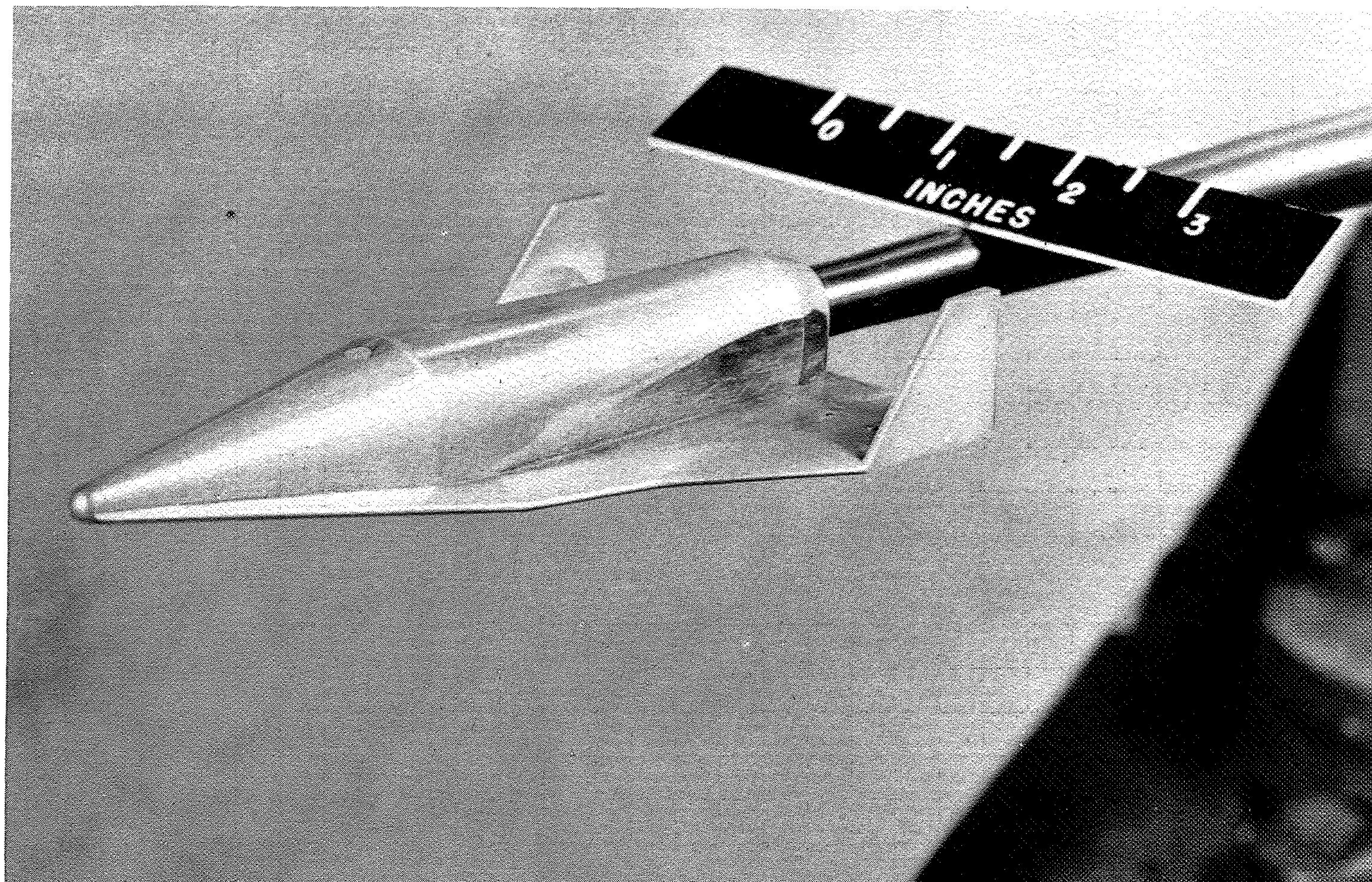

Figure 2.- Three-quarter front view of model $B_3W_5V_5$. L-58-661a

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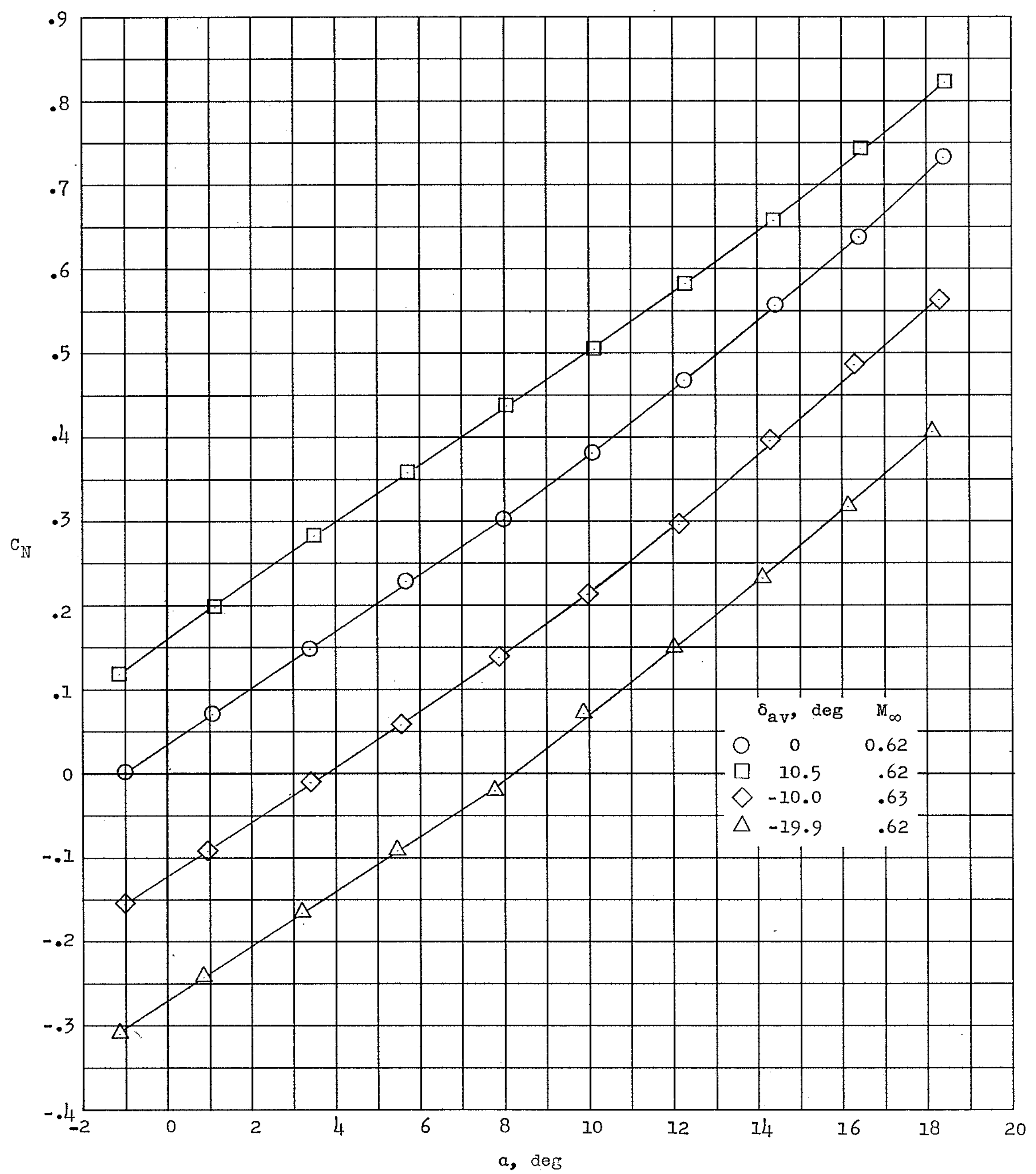

(a) C_N against α.

Figure 3.- Effect of symmetrical elevon deflection on the longitudinal aerodynamic characteristics at a Mach number of about 0.62. $\beta = 0^{\circ}$.

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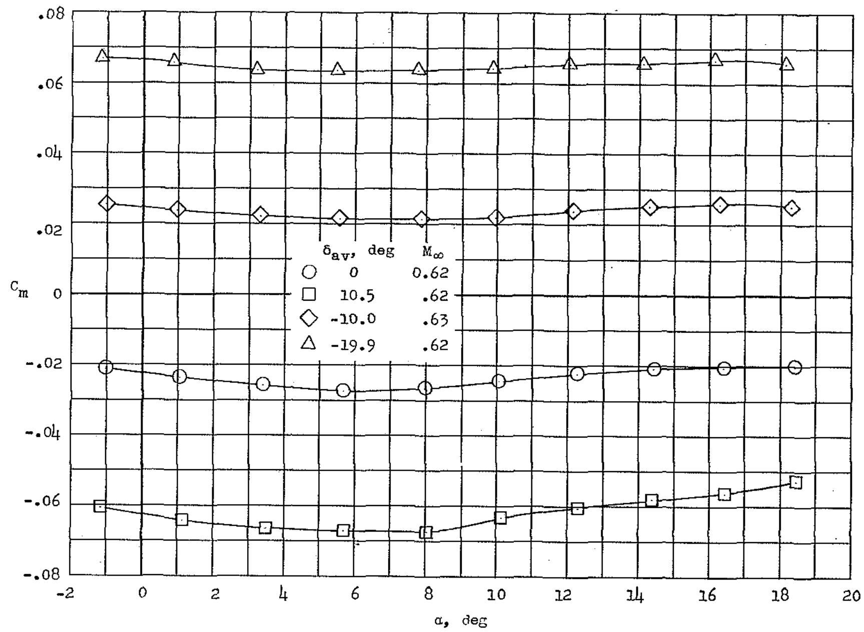
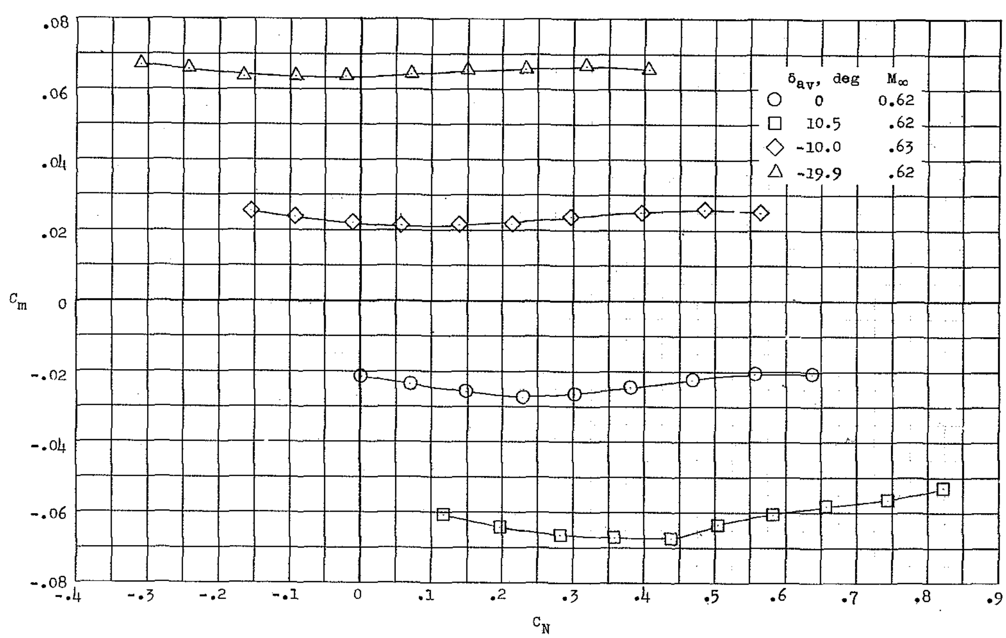


(b) C_m against α.



(c) C_m against C_N.

Figure 3.- Concluded.

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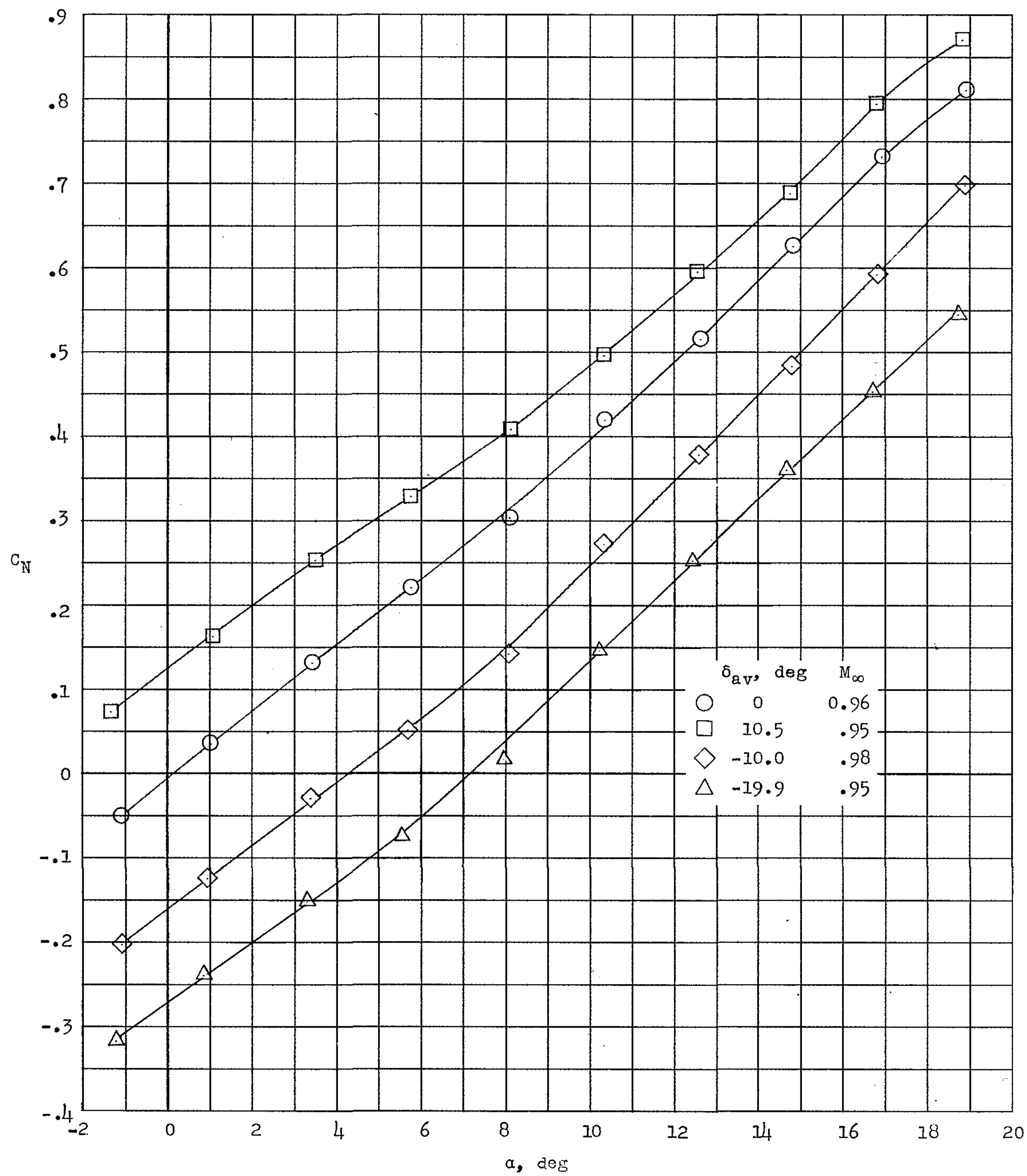

(a) C_N against α.

Figure 4.- Effect of symmetrical elevon deflection on the longitudinal aerodynamic characteristics at a Mach number of about 0.96. $\beta = 0^\circ$.

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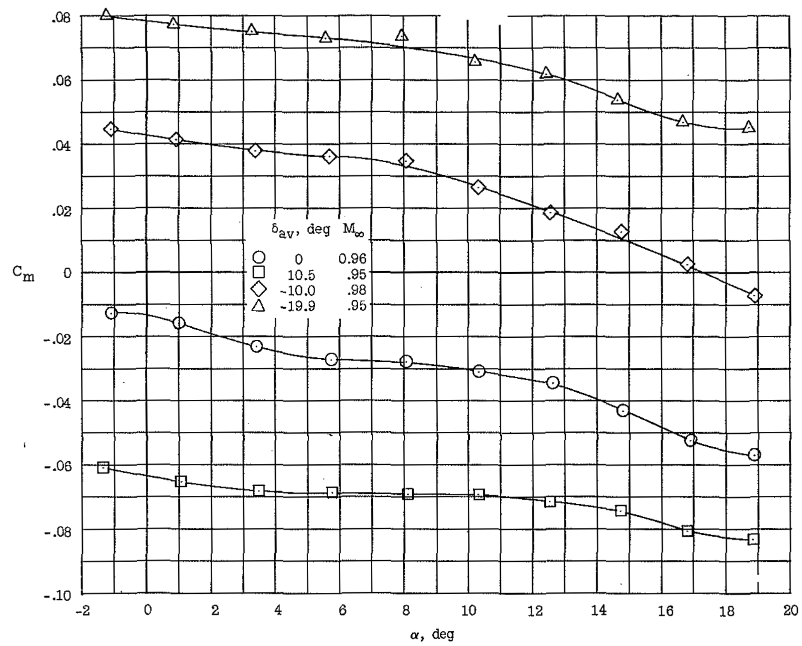
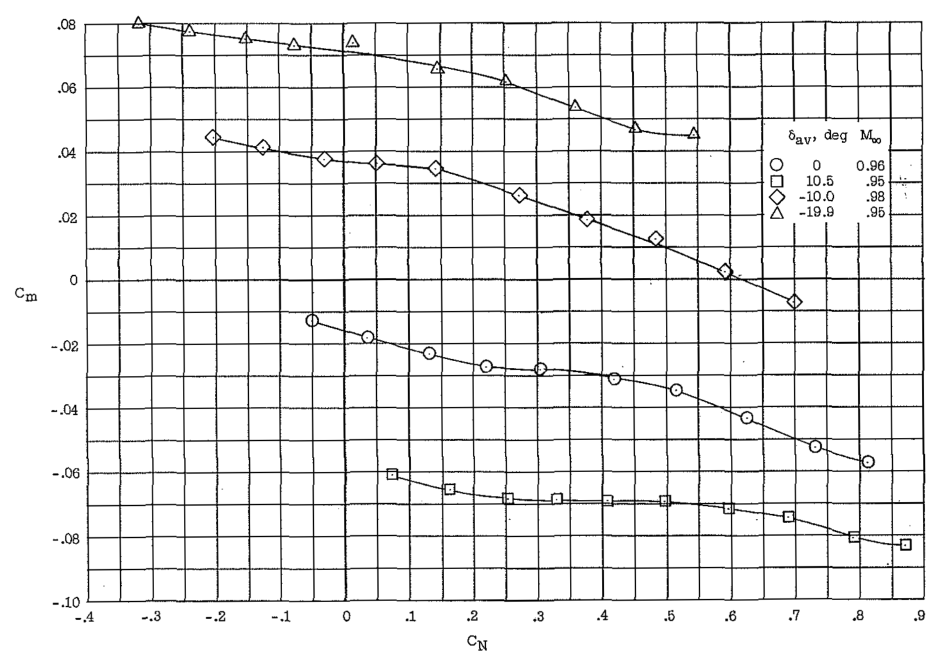


(b) C_m against α.



(c) C_m against C_N.

Figure 4.- Concluded.

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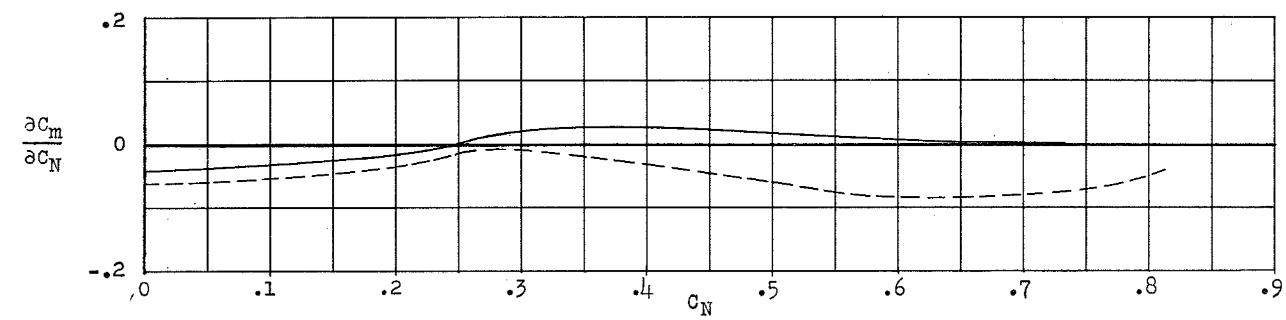
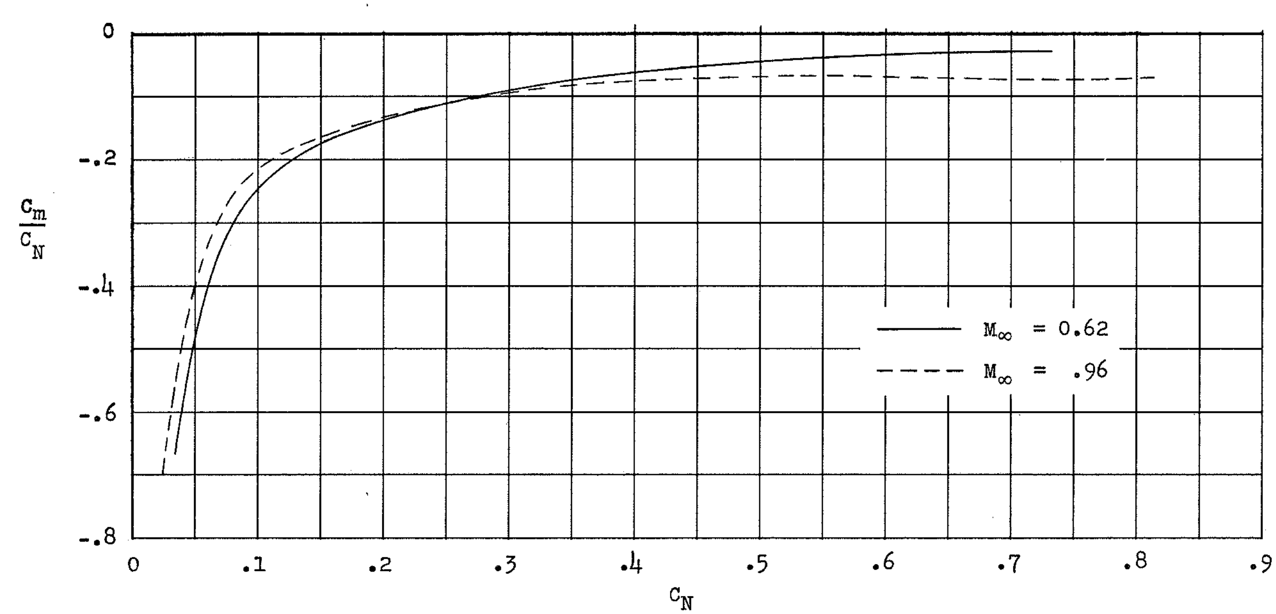


(a) Longitudinal stability parameter.



(b) Center-of-pressure location.

Figure 5.- Effect of Mach number on longitudinal stability parameter and center-of-pressure location. $\beta = 0^o$; $\delta_{av} = 0^o$.

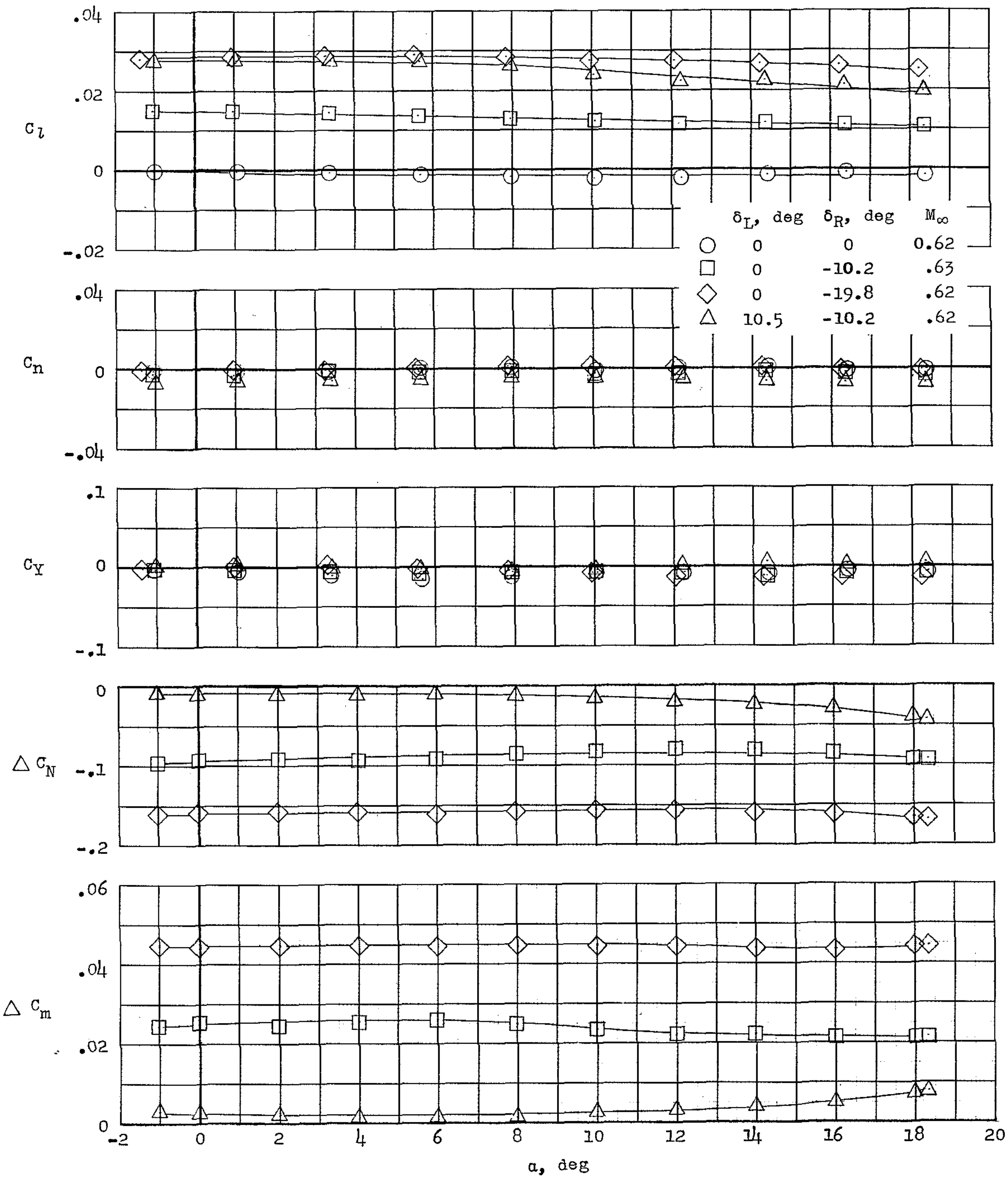


Figure 6.- Effect of unsymmetrical elevon deflection on lateral and incremental longitudinal aerodynamic characteristics at a Mach number of 0.62. $\beta = 0^\circ$.

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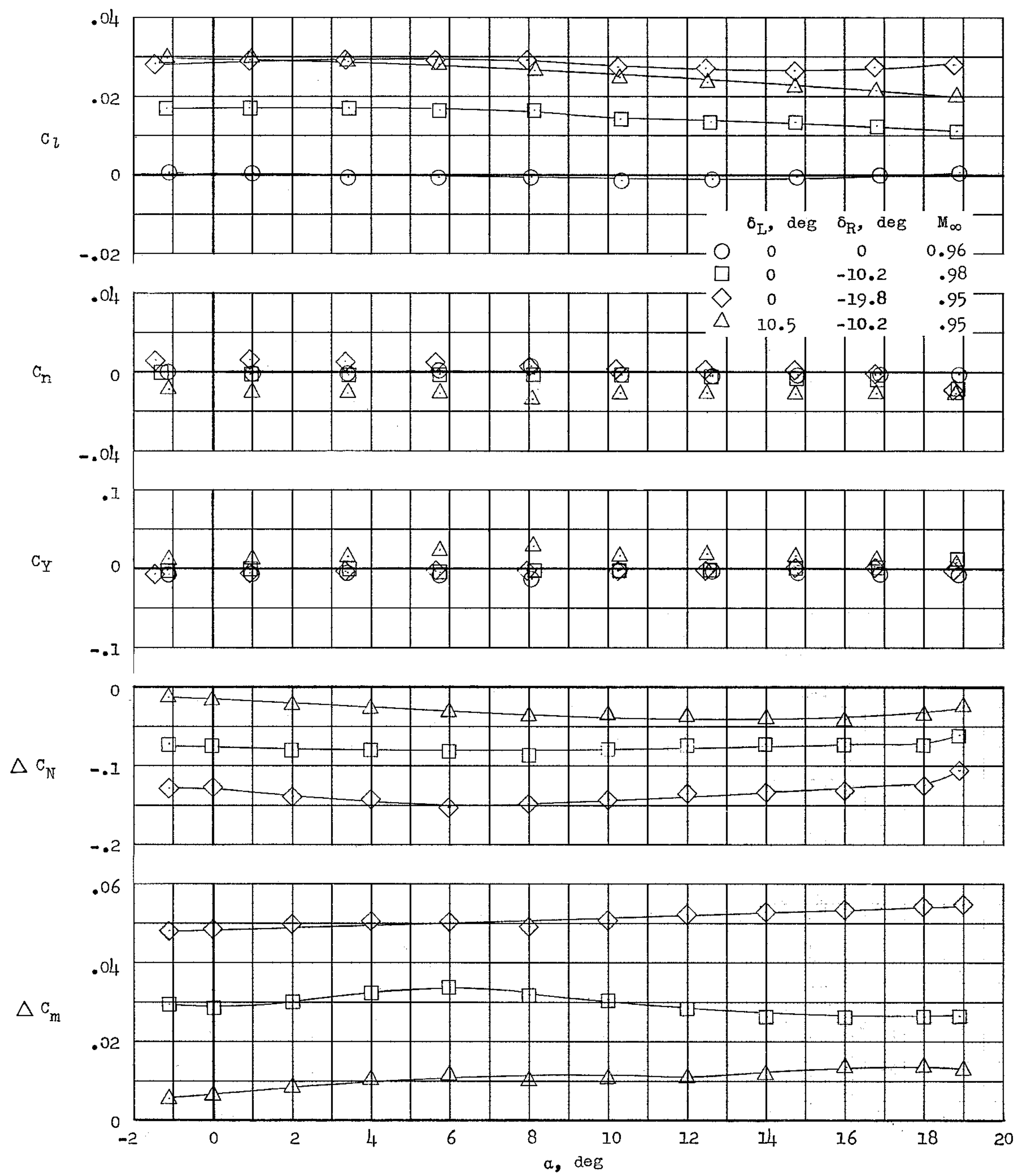

Figure 7.- Effect of unsymmetrical elevon deflection on lateral and incremental longitudinal aerodynamic characteristics at a Mach number of 0.96. $\beta = 0^{\circ}$.

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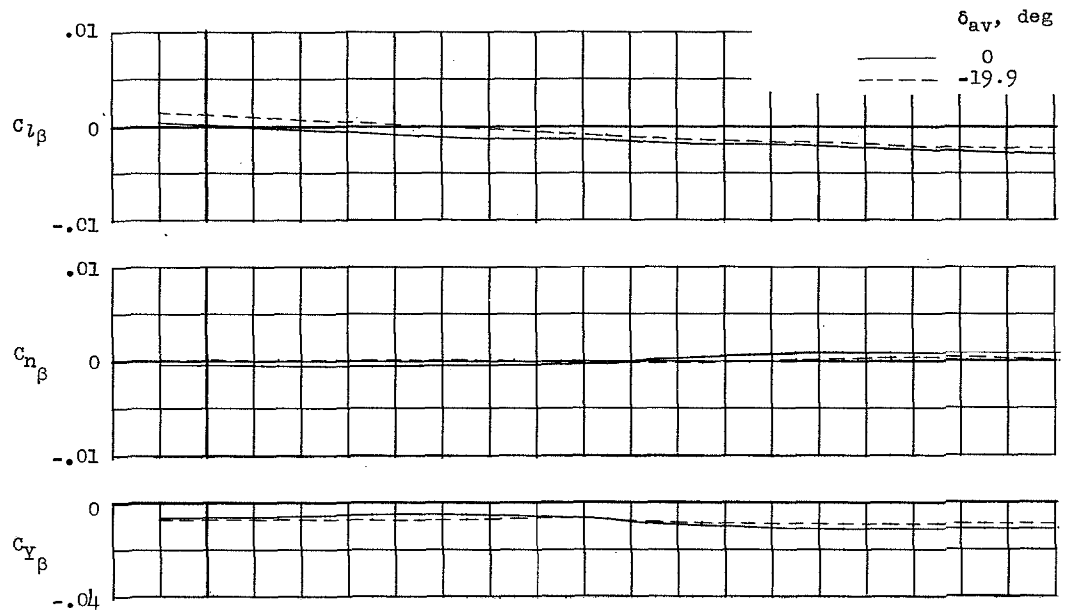
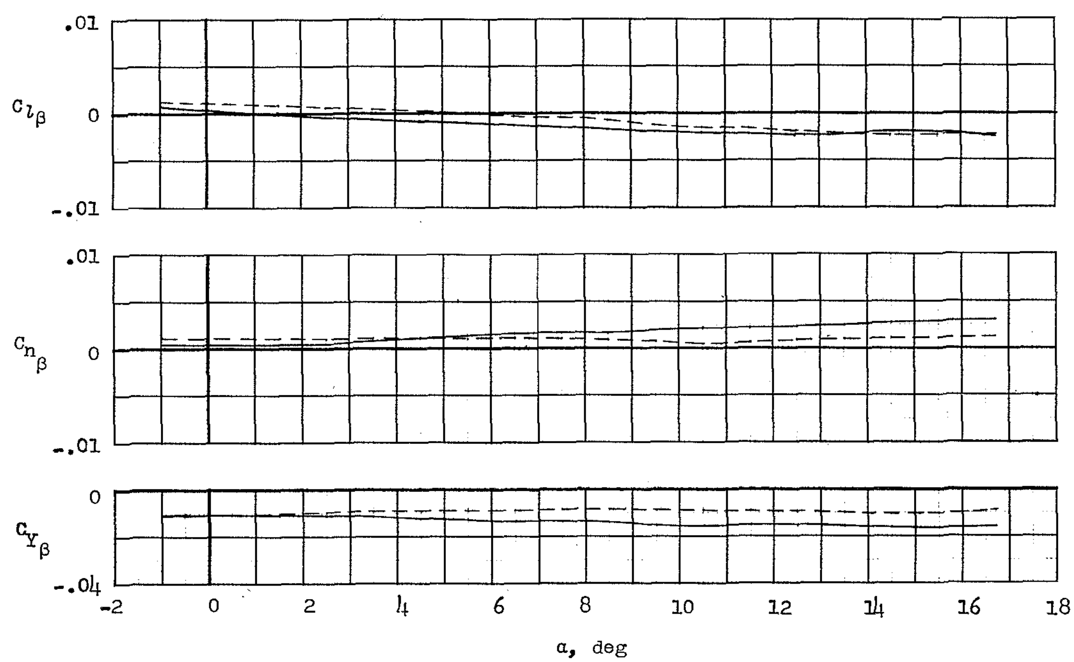


(a) $M_\infty = 0.62$.



(b) $M_\infty = 0.95$.

Figure 8.- Effect of angle of attack on lateral stability derivatives at Mach numbers of about 0.62 and 0.95.

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